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Abstract

A New Shield Design Method and Some Attenuation Studies in Laminated Biological Shields

E. Aalto [1], L. Hjärne [1], M. Leimdörfer [2]

A computer method has been developed to calculate the penetration of neutrons and gamma-rays through bulk shields. The attenuation and slowing-down of neutrons is treated by a combination of first-flight removal and multigroup-diffusion theories. The energy-dependent flux of such fission neutrons which are uncollided or have suffered only small-angle collisions is calculated throughout the shield; this flux provides source terms in a series of multi-group diffusion equations. Slowing-down between the diffusion groups is treated by a discrete-collision formalism in which the correct average energy loss of a neutron in a specific energy group is taken into account. Inelastic scattering and moderation by light nuclei come in naturally as slowing-down between all groups is permitted.

The transport of gamma radiation born in the reactor core and in the shield is calculated with a Monte Carlo scheme employing various variance reducing techniques, e. g. the exponential transformation whereby the outward directed motion of photons is enhanced and the slope of the source distribution is modified to be more favourable for Monte Carlo treatment.

The whole method is coded for the Ferranti Mercury computer. It includes an initial part which provides all the required neutron cross-section data. The gamma transport section has been translated to FORTRAN and exists in a version for the IBM 7090 computer.

The main advantage of the method presented is that it requires only a modest amount of computer time and capacity, compared to other systems giving the

1) AB Atomenergi, Stockholm
2) Research Institute of the National Defense, Stockholm

same quality and accuracy of results.

An extensive series of attenuation measurements in bulk shields has been performed at the Studsvik research centre. The radiation source has been the R2-0 reactor, furnished with special facilities for shielding studies. Measurements have been made up to $\sim$ 2 m penetration depths in a number of configurations of water - magnetite concrete - lead, in two configurations of water - ordinary concrete and, up to 0.5 - 1 m penetration depths, in configurations of layered iron and heavy water. Both neutron and gamma fluxes have been measured throughout the shields.

In order to study the accuracy and reliability of the method described, calculations have been performed in the same configurations, using the best available input values. For comparison, some calculations have been performed also with 1) an earlier 18-group removal method combined with a build-up factor treatment of gamma transport; 2) with a method calculating neutron fluxes by numerical integration of the Boltzmann equation; 3) with a neutron Monte Carlo code.

All of the methods mentioned above give a rather good agreement with the measured values, normally within a factor 2 - 3 after $\sim$ 2 m penetration.

As for the safety factors to be used when designing massive biological shields, we can draw the conclusion that the accuracy of the best available methods is so good that the uncertainty originating from other factors (e.g. radiation sources, concrete density) gives errors of the same order of magnitude as the calculation methods do.